

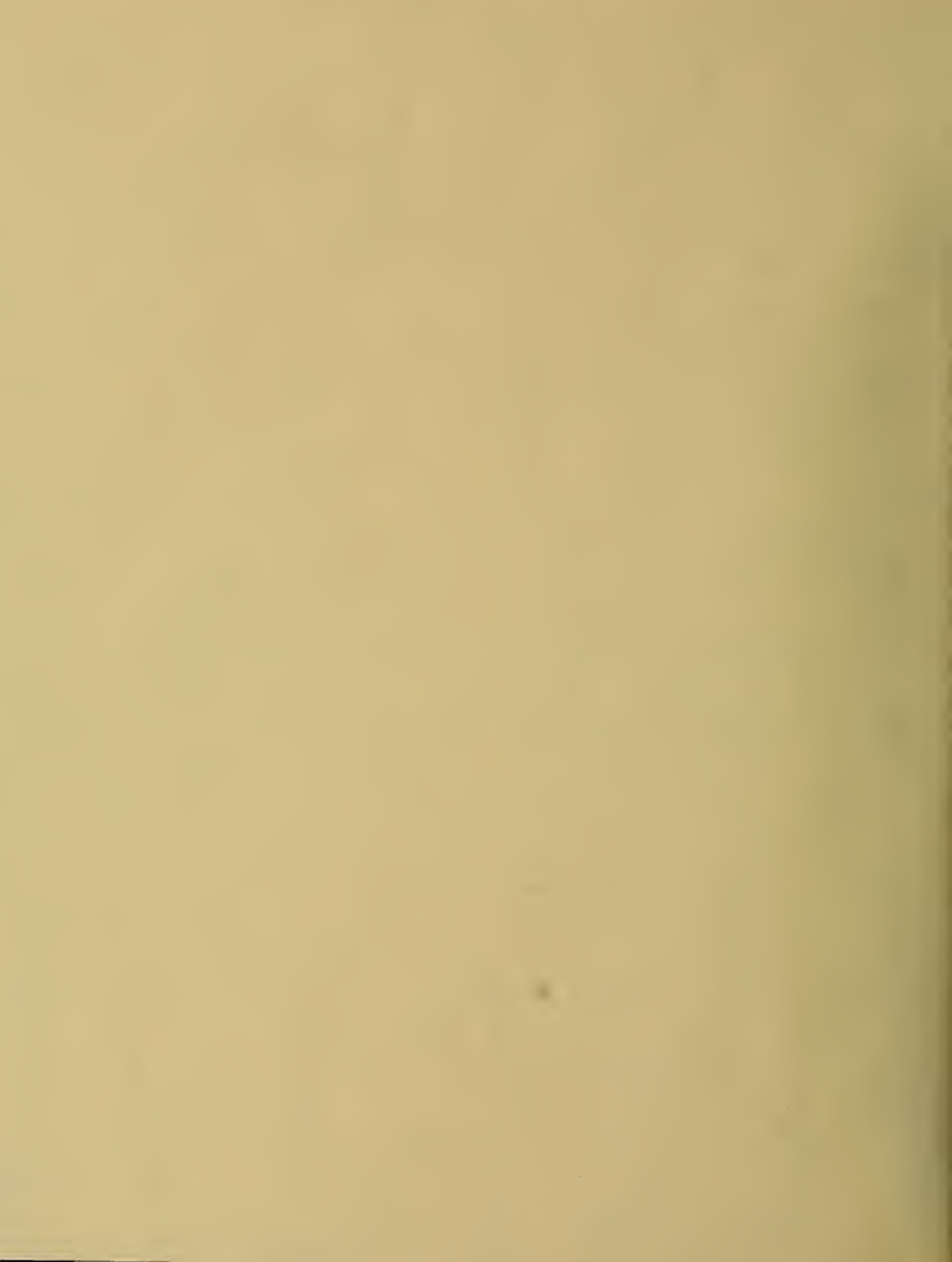
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# **An Analysis of Off-Highway Haulage Truck Maintenance and Repair Accidents, 1978-84**

By Dennis A. Long



UNITED STATES DEPARTMENT OF THE INTERIOR



Information Circular 9139

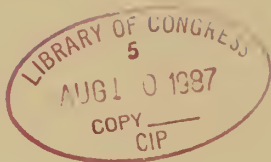
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**UNITED STATES DEPARTMENT OF THE INTERIOR**  
Donald Paul Hodel, Secretary

**BUREAU OF MINES**  
Robert C. Horton, Director



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## CONTENTS

|                                                              | <u>Page</u> |
|--------------------------------------------------------------|-------------|
| Abstract.....                                                | 1           |
| Introduction.....                                            | 2           |
| Safety hazard assessment for off-highway haulage trucks..... | 3           |
| Serious accidents and fatalities.....                        | 4           |
| Truck maintenance personnel.....                             | 5           |
| Truck maintenance shops and areas.....                       | 8           |
| Truck design for serviceability.....                         | 9           |
| Truck maintenance job procedures.....                        | 11          |
| Summary and conclusions.....                                 | 13          |
| References.....                                              | 14          |

## ILLUSTRATIONS

|                                               |   |
|-----------------------------------------------|---|
| 1. Truck accidents in U.S. surface mines..... | 3 |
| Truck maintenance accidents by--              |   |
| 2. Age.....                                   | 5 |
| 3. Job experience.....                        | 6 |
| 4. Job title.....                             | 6 |
| 5. Body part injured.....                     | 7 |
| 6. Commodity.....                             | 9 |

## TABLES

|                                                  |    |
|--------------------------------------------------|----|
| Truck maintenance accidents by--                 |    |
| 1. Days away from work.....                      | 7  |
| 2. System worked on.....                         | 10 |
| 3. Capacity, compared with truck population..... | 11 |
| 4. Activity of the injured.....                  | 11 |
| 5. Source of injury.....                         | 12 |
| 6. Tools and equipment.....                      | 12 |
| 7. Unsafe conditions.....                        | 13 |

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft      foot

st      short ton

h       hour

yd      yard

pct     percent

yr      year

# AN ANALYSIS OF OFF-HIGHWAY HAULAGE TRUCK MAINTENANCE AND REPAIR ACCIDENTS, 1978-84

By Dennis A. Long<sup>1</sup>

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## ABSTRACT

The size of off-highway trucks has increased substantially over the last decade, bringing about a radical change in truck maintenance practices and procedures. As a result, surface mine maintenance mechanics today are faced with the increased hazards of working with larger and heavier tools and components and doing repairs at greater heights, thereby exposing them to a high potential for serious injury or death. Not surprisingly, the number of accidents involving truck maintenance mechanics is significantly increasing.

The Bureau of Mines has assessed the haulage truck maintenance safety problem, analyzing maintenance-accident data over the 7-yr period, 1978-84, in terms of personnel, job activities, truck components and systems, tools involved, and truck design. This assessment, based on the review and interpretation of 1,225 haulage truck maintenance accident reports, identified major factors contributing to these accidents. Overall, young, inexperienced workers are involved in most accidents. A typical maintenance accident involves a male mechanic under 33 yr old, with less than 5 yr job experience.

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## INTRODUCTION

Over the past decade, surface mine maintenance and repair operations have changed radically. The number of maintenance personnel has grown along with the hazards of working with larger and heavier components at greater heights and with larger and heavier tools. Furthermore, transfer of skills from over-the-road vehicle mechanics is not as feasible as it once was, because of the ever-increasing size of mining equipment and the complexity of its design. In short, surface mine equipment maintenance and repair has become increasingly sophisticated as well as labor intensive, necessitating further research and evaluation in terms of both safety and efficiency (1, 7-8).<sup>2</sup>

Maintenance and repair operations in U.S. surface mines, during the 1978-84 period, accounted for 34.1 pct of all surface mining lost-time accidents and 16.5 pct of all fatalities (12). A study in 1974 analyzed maintenance accidents in metal-nonmetal mines, showing that 22.7 pct of the surface mining accidents were charged to maintenance (13). Thus, despite the differences in population between the two studies, there is evidence toward a rising trend in the proportion of maintenance accidents to all surface mine accidents.

During the 1978-84 period, surface mining accounted for about one-third of all mining accidents and one-third of all mining fatalities. In U.S. surface mines during the 7-yr period, there were 18,331 maintenance-related injuries and 67 fatalities. This resulted in 243,827 lost days and 15,414 restricted days (12).

Despite the increasing safety hazard and the significant potential for improvements in efficiency and productivity, little effort has been made to evaluate maintenance safety or to initiate improvements (8, 13). This is due, in part, to the fact that mine management traditionally concentrates first on production-related problems over

maintenance, but also because of the overall difficulty in managing the wide spectrum of maintenance activities and concerns (6). Thus, lacking the means to assess current performance and accurately identify improvements, mines and plants unknowingly have missed the potential for improving performance, safety, productivity, and subsequently, profitability through better maintenance of equipment (4, 6, 14).

From the analysis of Mine Safety and Health Administration (MSHA) computer listings of all U.S. surface mines (12) during the 1978-84 period, and the findings of previous research (1, 3), surface mine maintenance and repair operations are expected to continue to change drastically through the year 2000, because of the--

Increasing mechanization of individual mining operations and off-road equipment;

Increasing size and complexity of equipment design as well as shop ancillary equipment; and

Changes in the demographics of the surface mining industry. Because of the extensive layoffs of younger employees during the recent mining recession, there will likely be a future shortage of experienced mechanics as the more experienced, older mechanics retire.

Maintenance and repair is a key area on which to focus attention in order to reduce injuries in U.S. surface mines. There is a lack of information on maintenance safety, and this area may well be a new frontier for safety professionals. Past industrial hazards work has focused attention mainly on such areas as slips and falls of persons or on vehicle collisions. However, there is relatively little information on specific mine maintenance hazards. This may be due to the fact that it is a difficult area to assess because of the great variety of job procedures, tools, equipment, and shop conditions.

<sup>2</sup>Underlined numbers in parentheses refer to items in the list of references at the end of this report.

During the past 10 to 15 yr, the Bureau has been responsible for many technological advances that have provided increased safety for mining operations, but additional areas of research have been identified. Interest in mine worker safety has prompted the Bureau to investigate surface mine maintenance safety (8, 10-11). Because of its essential role in surface mining operations, as well as initial research that indicated a declining safety record, haulage truck maintenance and repair activities were targeted for initial investigation. This report summarizes the data collected, providing

baseline information on the industrial hazards associated with haulage truck maintenance and repair activities in U.S. surface mines. Additional maintenance and repair information has been obtained from two Bureau research studies (1, 3), which included a broad-based survey of mine practices across the United States. A review of the data suggests that there are both human factors and ergonomic and engineering design problems in the truck maintenance operations. The evidence also shows that these problems contribute to accidents, injuries, and fatalities.

#### SAFETY HAZARD ASSESSMENT FOR OFF-HIGHWAY HAULAGE TRUCKS

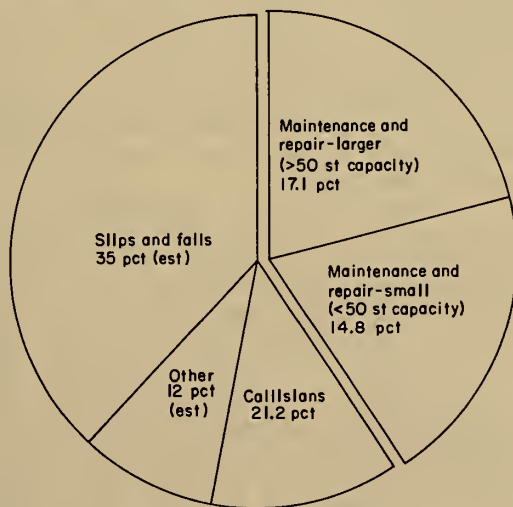
This report summarizes information taken from Mine Safety and Health Administration (MSHA) accident records to further delineate the growing maintenance safety problem (12). Recommendations are based on information taken directly from the accident reports, combined with discussions with industry contacts. Surface mine haulage trucks were selected for this study since they are the predominant vehicle in surface mine equipment fleets, and it was anticipated that haulage truck accident trends would closely parallel other surface equipment.

In U.S. surface mines, over the 1978-84 7-yr period, there were 7,160 truck-related accidents, such as slips and falls, collisions, maintenance, and other accidents. This accident category includes all trucks, including off-highway and on-highway haulage vehicles, as well as service trucks and other nonhaulage vehicles that are also used as a part of the maintenance function.

All of the 7,160 surface mine truck accident reports (12) were inspected, and the 1,225 off-highway haulage truck maintenance accidents during the 7-yr period were reviewed and coded, using accident factors pertinent to maintenance. The study included accidents involving all personnel, regardless of job title, performing maintenance and repair on off-highway haulage trucks of 50-st or greater capacity. This includes service vehicles utilized in the maintenance of these vehicles and ancillary maintenance

activities that are directly related to haulage truck maintenance, such as rebuild shops or parts warehouses. The activities include all preventive maintenance, inspections, repairs, lubrication, cleaning, towing, and maintenance supervision.

As an overview of the 7,160 surface mine truck accidents (fig. 1) that were reviewed, 31.9 pct (2,284) were attributed to maintenance and repair activities. The maintenance and repair of the larger, 50-st or greater capacity haulage vehicles accounted for 17.1 pct



(7,160 total surface mine truck accidents)

FIGURE 1.—Truck accidents in U.S. surface mines.

(1,225) of the total mine truck accidents. Maintenance and repair of trucks less than 50-st capacity accounted for 14.8 pct (1,059). Single truck accidents or collisions contributed 21.2 pct of all accidents (12). Of the remaining 46.9

pct of the truck accidents, other Bureau research has confirmed that roughly 35 pct are due to slips and falls (9). Thus, the remaining estimated 12 pct of the accidents would include all other categories (12).

#### SERIOUS ACCIDENTS AND FATALITIES

A review of the accident data base and MSHA Fatalgrams revealed that eight reported fatalities involving 50-st or greater capacity off-highway haulage truck maintenance and repair were recorded during the 7-yr period 1978-84 (12). A brief analysis of each fatality is presented to give a perspective of the wide spectrum of conditions that can be present where people are killed:

1. A tire vendor in Indiana was unloading large truck tires at the mine shop using hooking chains on a hydraulic hoist. The chain slipped, causing the tire to fall 6 ft onto the man, crushing him. The vendor was 55 yr old and had 2 yr of job experience and 30 yr of total mining experience. This fatality shows the need to monitor outside contractors who work on the mine property.

2. A mine laborer in Arizona, who was operating the maintenance service truck, was sent to the machine shop to pick up a truck part. A boom truck backed over him as he faced the back of his service truck. The laborer was 40, with 14 yr of job experience and 19 yr mining experience. This fatality shows the wide spectrum of activities that encompass maintenance and repair.

3. A truck driver in Texas was servicing a haulage truck in the field when an unattended, empty haulage truck rolled 100 yd downgrade, struck the truck being serviced and drove the left drive tire over him. The truck driver was 19, with no experience. This fatality shows one of the inherent dangers involved with conducting field maintenance, rather than towing the disabled vehicle to the shop.

4. A mechanic in Nebraska was working under a raised and blocked truck bed. After 3 h of stability the blocks kicked out, crushing the employee. The mechanic

was 28, with 2 yr of both job and mine experience.

5. A truck driver in Tennessee was servicing a truck hoist mechanism when the truck bed fell, pinning his head and neck between the bed and the frame. The truck driver was 56, with 7 yr of both job and mine experience.

6. A mechanic in Kentucky was charging an air tank. During the procedure the truck operator was told by a third employee to move the truck, and he thus ran over the mechanic. The mechanic was 59, with 13 yr of job experience and 30 yr of mining experience. This fatality shows the dangers associated with working around large equipment and the need for good communication.

7. A mine laborer in West Virginia was assisting on a maintenance task that involved a winch line. When the winch stand broke, the cable hit the mine laborer, propelling him into a brick wall. The laborer was 28, with 2 yr of both job and mine experience.

8. A mechanic in Nebraska was working under a partially raised truck bed which was blocked up by shop stands. The stands kicked out crushing the employee. The mechanic was 59, with 13 yr of job experience and 30 yr of mine experience.

Over the same 7-yr period, there were 19 serious accidents reported, each resulting in disabling injuries (12). The average disability resulted in 29.2 lost days. The most frequent type of serious accident was amputation of body parts, most often fingers or hands; these accidents were usually caused by close quarters or confined access points. There were nine such disabling injuries reported. Ruptures due to overexertion accounted for six accidents. One injury involved a man getting pinned between a

haulage truck and a service truck. Another injury involved a serious fall from a truck frame while steamcleaning.

Finally, there were two disabling injuries involving a fall of a truck box.

#### TRUCK MAINTENANCE PERSONNEL

Young, inexperienced workers are involved in the majority of haulage truck maintenance accidents. Workers under 25 yr old were involved in 19.6 pct of all accidents, while those under 35 yr were involved in 55.8 pct of all accidents. Figure 2 summarizes truck maintenance accidents by age of the injured employee. Figure 3 summarizes truck maintenance accidents by job experience. Workers with less than 1 yr experience in the particular job held at the time of the accident accounted for 19.9 pct of all accidents; 68.1 pct had less than 5 yr of job experience. Men are involved in 98.4 pct of all accidents, while women 1.6 pct. It should be noted that surface mine maintenance workcrews usually have a greater share of older, more experienced

employees than other work crews. Since young, inexperienced personnel comprise a very small percentage of the maintenance personnel, the data would suggest an even higher incident rate for these employees (12).

Job titles of mining personnel involved in truck maintenance accidents are presented in figure 4. Maintenance personnel, including mechanics, helpers, and trainees, accounted for 67.8 pct of the accidents, while mine equipment operators and laborers accounted for almost a quarter of them (12).

To examine the nature of the injuries, table 1 presents haulage truck maintenance accidents by days away from work (12). Of the maintenance accidents examined, 36.3 pct involved no lost time

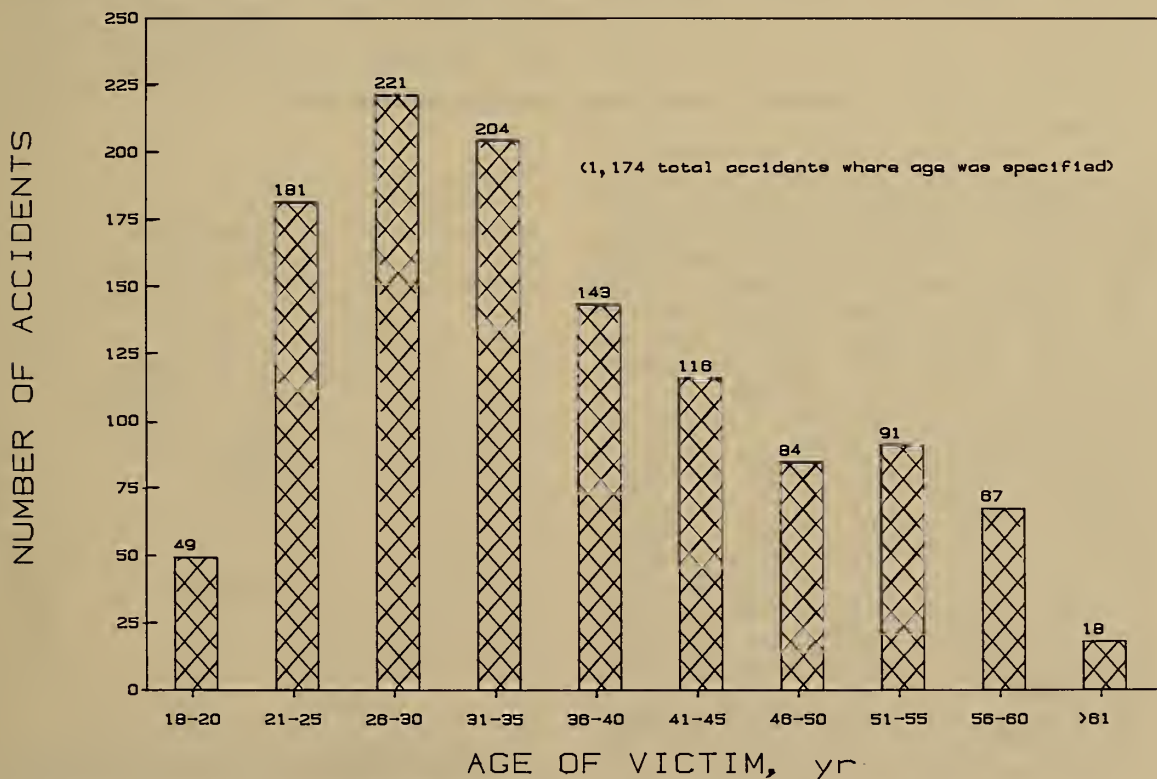


FIGURE 2.—Truck maintenance accidents, by age.

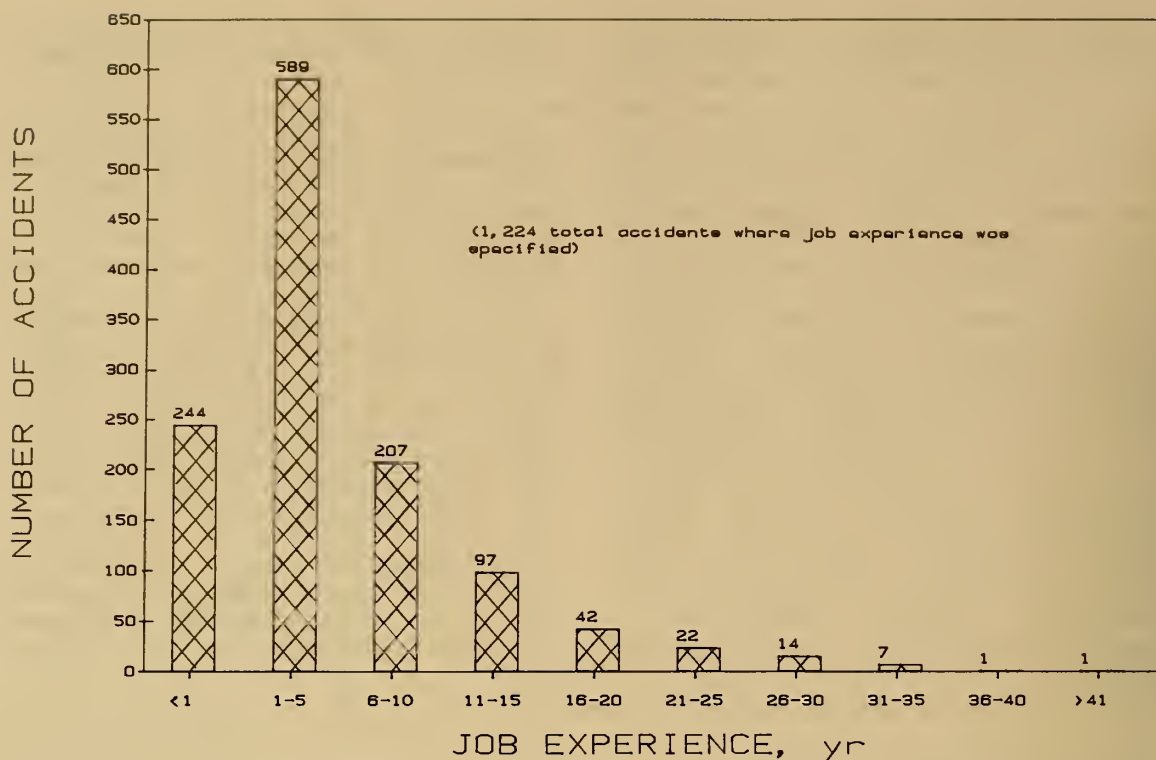


FIGURE 3.—Truck maintenance accidents, by job experience.

and 39.0 pct involved between 1 and 15 lost days. For comparison purposes, 39.3 pct of all U.S. surface mining accidents have no lost time. Of the accidents with lost time, there was an average of 24.0 lost days and 1.5 restricted days. In 1977 each maintenance accident involved an average of 22.0 lost days, increasing incrementally each year through 1984; in 1984 each accident involved an average of 28.5 lost days, indicating an increasing trend toward more lost days per accident. This rising trend seems to be true in all segments of the mining industry. Field-gathered information from the mining industry indicates that maintenance also accounts for a high percentage of the nonreportable type accidents. These less severe, "knuckle busting" accidents are more common in maintenance, and they increase costs and decrease productivity, but often do not show up directly in the reported accident statistics (1).

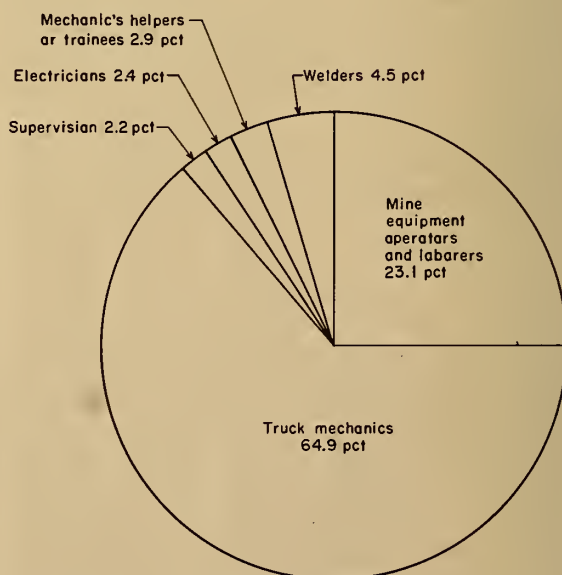


FIGURE 4.—Truck maintenance accidents, by job title.

The body part injured in truck maintenance accidents is presented in figure 5, with the data grouped into major categories (12). Head and neck injuries account for 14.3 pct of the injuries. Major body injuries, involving the chest, back, hip, or trunk, totaled 18.0 pct. Back injuries from manual exertion involved 9.6 pct of the injuries. Multiple injuries totalled 9.9 pct; these injuries are not recorded in the specific body part categories. It appears that

TABLE 1. - Truck maintenance accidents, by days away from work<sup>1</sup>

| Lost days            | Number | pct   |
|----------------------|--------|-------|
| 0.....               | 437    | 36.3  |
| 1 to 6.....          | 303    | 25.2  |
| 6 to 16.....         | 166    | 13.8  |
| 16 to 31.....        | 121    | 10.0  |
| 31 to 61.....        | 107    | 9.0   |
| Over 61.....         | 69     | 5.7   |
| Total specified..... | 1,203  | 100.0 |
| Not specified.....   | 22     | NAp   |
| Total accidents..... | 1,225  | NAp   |

NAp Not applicable.

<sup>1</sup>Not counting restricted days where the employee is away from the normal job task.

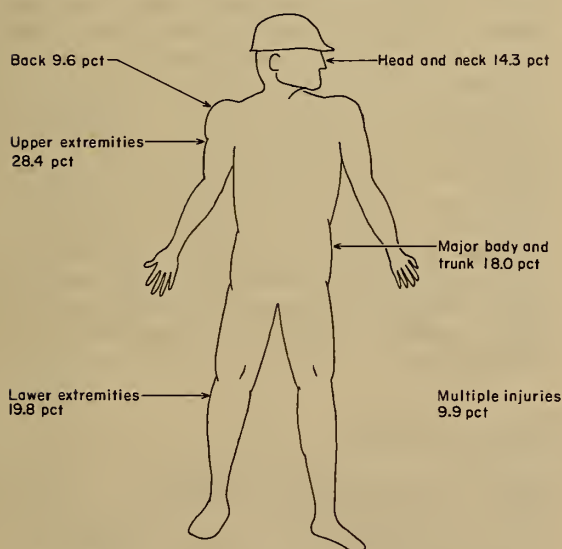


FIGURE 5.—Truck maintenance accidents, by body part injured.

truck maintenance injuries most commonly involve the upper and lower extremities, accounting for 48.2 pct of all accidents.

Injuries were most often due either to the employee's lack of training for the particular job at the time of the accident or to the employee's conducting the job in a nonrecommended manner. When looking for the primary cause of the maintenance accidents, unsafe actions account for 63.6 pct of all accidents; this category would include taking an unsafe position, using equipment unsafely, nullifying safety devices, and failing to use a platform or personal protection (12). The primary cause of about one-fourth of all accidents were due to the worker's taking an unsafe position; for example, reaching beyond one's lifting radius or attempting to climb a ladder with a heavy part in hand.

While unsafe actions or human errors account for the majority of all truck maintenance accidents, equipment design deficiencies caused 28.0 pct of the accidents (12). This category includes accidents that clearly involved the design of the vehicle; for example, where the only way to remove a truck part is to manually lift through a confined opening. It seems likely that a portion of the accidents due to unsafe actions may well have been mitigated through equipment redesign for serviceability. Thus, although the primary cause of the maintenance accident is unsafe actions on the part of the employee, there may be ways to prevent such human error accidents through equipment redesign.

Another primary cause of accidents is the failure to secure, resulting in 6.9 pct of the accidents, including improper support of heavy parts and components or an unexpected release of energy. Finally failure to warn or signal caused 1.5 pct of the accidents (12).

Because of the significant number of accidents due to unsafe actions taken by mine personnel working on truck maintenance, it appears that improved skills training would be an effective way to reduce accidents. Further examination of the accident reports reveals that the people assigned to maintenance were--

1. Performing tasks for which they were not formally or adequately trained. This includes both equipment operators doing maintenance-type work and maintenance mechanics moving a piece of equipment to and from the shop. Again, almost one-fourth of all haulage truck maintenance accidents involved mine equipment operators or laborers.

2. Not following prescribed procedures or safety precautions. This might include disregarding lockout procedures, nullifying a safety device, or just not doing the job as instructed.

3. Working with inadequate or improvised tools and equipment. Without the proper tools, it may be very difficult to complete a job without taking an unsafe action.

Despite the importance of mechanic training, training alone will not alleviate the hazards to the maintenance employee. Because of the great variety of makes and models of haulage trucks in any individual mine fleet, the maintenance and repair department must service a broad range of mechanical and electrical equipment, covering a vast number of tasks and procedures involving different tools, equipment, and mechanic expertise. This is further complicated by the variety of mining equipment services, job procedures, tools, equipment, and shop conditions, and the many equipment modifications found at each mining operation (1, 3).

Increased training would help alleviate the safety hazard inherent in the job. Most maintenance training in the mines consists of safe work briefings followed by on-the-job experience under either a lead mechanic or a more senior employee. Instruction varies depending upon the teaching skills and job experience of the supervisor. Emphasis should be on

recognizing specific hazards, knowing proper job procedures for the various truck models and systems, and correct use of tools and equipment (3).

The training materials most needed by mines are effective, easy-to-use troubleshooting guides. Fewer than half of the equipment manufacturers provide such guides for their products (3). Most of the available guides need to be improved substantially in terms of both readability and ease of use. Also needed are well-designed guidebooks for specific maintenance tasks, such as a manual on the haulage truck electrical system, cooling system, hydraulics, electronic components, etc. (3). Several manufacturers have materials that can be purchased, but they cover only a limited number of maintenance tasks on a specific truck system. Future research is needed to characterize design guidelines for maintenance service manuals (3).

It is also important to correctly assign only qualified maintenance personnel to specific maintenance tasks. For example, over one-fourth of the truck maintenance accidents involved mine equipment operators, who were, for the most part, untrained in maintenance-type work. Also, the more skilled mechanics are often assigned to routine tasks, such as transporting equipment to the shop, that could be handled by less experienced mechanics (1).

Mechanics should also be trained and qualified to operate the equipment they maintain. Although their job involves moving equipment around the shop area, mechanics are often not adequately trained to operate the vehicles they service. Mechanics should be familiar with the control functions of the vehicles they repair in order to minimize the safety hazard (1, 3).

#### TRUCK MAINTENANCE SHOPS AND AREAS

The majority of accidents occur in the shop facility where the maintenance and repair activities usually take place. Specifically, 67.3 pct of all haulage truck maintenance accidents, for the years 1978-84, occurred in the shop,

while the remainder (32.7 pct) occurred in the field (12).

The importance of accident location increases when it is considered that most maintenance activities do take place within the shop facilities. The mining

companies surveyed reported that approximately 85 to 90 pct of the truck maintenance and repair worktime is completed in the shop (1). If the accident distribution was normal one would expect a similar proportion of the accidents (85 to 90 pct) to occur within the shop facility. Although 32.7 pct of the accidents in this study occurred in the field, only about 10 to 15 pct of the maintenance worktime involves field maintenance. Accordingly, field maintenance work is two to three times as hazardous as work completed within or around the shop facility.

One way to counter the hazards of field maintenance work is to develop and use towing vehicles capable of moving disabled haulage trucks back to the shop. Usually, towing a large haulage truck is very difficult, involving two or more support vehicles and additional personnel. And because of the cost, it is not common in the United States to have specialized towing vehicles. Another solution might be to retrofit the truck so that it can be towed more easily (1).

Improved physical design of maintenance shops and equipment bays could help reduce accidents. Important factors are shop organization, housekeeping, illumination, and transporting of parts. Poor condition of tools and equipment contributes to a significant portion of the accidents studied. An effectively designed workspace could enhance productivity, allow more efficient use of tools, and improve safety. At least 3 pct of the accidents involved poor housekeeping practices in some way (12).

From the analysis of the maintenance accidents, combined with mine visits, it is apparent that poor workspace organization is common in many surface mining shop facilities; it is manifested as follows:

Handtools and small power tools strewn about or stored wherever space permitted, forcing people to climb over or reach around them.

Tools or parts not conveniently located, forcing people to look for them or do without.

Shop floors covered with cables and hoses, presenting tripping hazards.

Work performed on oil or grease splattered floors or on unimproved rocky ground in the field.

In addition, because most haulage truck shops service larger trucks than they were originally designed for, workspace is at a premium. Quite commonly there is insufficient space between truck bays to use tire grabbers or forklifts to handle heavy parts. Further research is needed to analyze and improve the total maintenance system as it functions within the shop facility (1).

Some environmental hazards are present in shop facilities (1, 3). For example, it is common for welding to be done inside the shop buildings, and shop exhaust systems are often ineffective in evacuating the fumes. Another problem of much concern is with lighting; in most mine shops illumination levels are generally below accepted industry standards. Noise levels are often very high in shops, particularly where electric arc welding is performed.

Another important truck-shop problem is communication. As previously mentioned, the failure to warn or signal was the primary cause of 1.5 pct of the accidents and at least one fatality. Frequently, there are two or more people working on or around large mining equipment at any time. It is important that these people can communicate their intentions and actions to each other. Simple solutions could include lockout equipment or proper tagging of which truck is being repaired (1).

Figure 6 illustrates the breakdown of truck maintenance accidents by commodity. Surface coal mining accounts for 51.3 pct of all accidents, with surface metal mining second at 26.7 pct.

#### TRUCK DESIGN FOR SERVICEABILITY

Some maintenance problems are associated with the poor design of the truck

for routine or major maintenance. Improvements in design would substantially

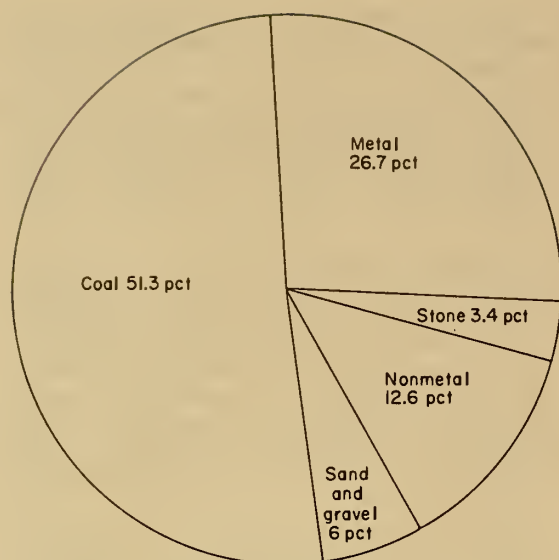


FIGURE 6.—Truck maintenance accidents, by commodity.

TABLE 2. - Truck maintenance accidents, by system worked on

| System                     | Number | pct   |
|----------------------------|--------|-------|
| Engine.....                | 173    | 21.3  |
| Truck body.....            | 153    | 18.8  |
| Drive train.....           | 100    | 12.3  |
| Tires and wheels.....      | 93     | 11.4  |
| Cooling.....               | 67     | 8.3   |
| Brakes.....                | 51     | 6.3   |
| Electrical.....            | 47     | 5.8   |
| Hydraulic.....             | 40     | 4.9   |
| Suspension.....            | 35     | 4.3   |
| Steering.....              | 20     | 2.5   |
| Wheel motors.....          | 12     | 1.5   |
| Exhaust.....               | 9      | 1.1   |
| Towing vehicle to shop.... | 12     | 1.5   |
| Total specified.....       | 812    | 100.0 |
| Not specified.....         | 413    | Nap   |
| Total accidents.....       | 1,225  | Nap   |

Nap Not applicable.

reduce maintenance time and maintenance-related injuries (1, 3). Table 2 presents accident frequency data for various systems of off-highway haulage trucks (12).

The accident data indicate that the most accidents occur while working on the engine, truck body, drive train, or tires and wheels, while the lowest number of accidents occur with the exhaust and wheel motors. Overall, the body, tires and wheels, engine, and drive-train account for 63.8 pct of the accidents where a system was specified, indicating a possible correlation between number of accidents and the size and scale of the component or part to be worked on (12). Further research is needed to correlate truck system worktime to the accident rates, giving hazard exposure rates.

Recommendations for improved truck design should be matched with redesign of components, procedures, tools, and manuals. Based on the accident data (12), previous research (1, 3), and industry contacts, the main design problems include--

Poor access to vehicle parts or areas of the unit such that routine maintenance tasks are overly complex;

Inadequate access openings, clearances, and visibility to permit a person to reach in or climb in for tasks to be performed;

The need to remove or dismantle ancillary components in order to gain access to the failed unit;

Designing truck parts that require relatively unskilled mechanics to perform complex sequence of tasks in order to repair equipment; and

Requiring mechanics to manipulate oversized, heavy vehicle components in tight spaces with inadequate clearances, supports, or tools.

Because of the size and complexity of many haulage trucks, these design problems can interact to make maintenance and repair more difficult, and often more hazardous. This can be further complicated by the lack of adequate tools available to correctly perform the required maintenance task or the need to perform certain repairs in the field without the resources typically available in the shop area.

One of the most hazardous maintenance tasks is the removal, repair, and replacement of oversize truck tires (3). In reviewing accident reports, it became obvious that procedures for de-airing, airing, removing, and replacing tires are

inadequate. One out of five of all tire and rim accidents involved a tire explosion, usually causing serious injury or death to mechanics in the vicinity of the explosion (12).

In some cases, specific equipment modifications, both at the factory and at the mine, would help alleviate above-normal hazards. In most cases, the changes would involve original equipment options to be offered by the truck manufacturers. However, options that would enhance maintenance safety are often ignored, since the mine's safety department rarely can affect truck purchasing decisions (1).

Table 3 lists truck maintenance accidents by truck capacity (payload), compared with estimated truck populations (12). From these data it is apparent that the 50- to 85-st-capacity trucks have twice the maintenance safety hazards than the 150-st-capacity trucks. This seems to correlate with the data that show access to be a major factor in truck maintenance safety, as the larger capacity trucks have greater space between truck components.

#### TRUCK MAINTENANCE JOB PROCEDURES

Further analysis of the data determined the cause of the maintenance accidents. Table 4 lists accidents by activity of the injured (12). These generic activity descriptions were created to simplify the data analysis. Movement around the shop area, and up and down the mobile equipment, accounted for over one-third of the injuries studied. This number reflects the need for adequate work platforms, access steps and ladders, and good house-keeping. Mechanic training should include the broad range of activities that are included in the maintenance task, such as knowledge of the location and ease of access to the parts in the shop.

Removing and replacing parts during maintenance activities accounted for 26.5 pct of the accidents where the maintenance activity could be determined. Frequently, a truck part was either too heavy or out of reach, resulting in strains, sprains, or crushed or lacerated fingers when the part was accidentally

TABLE 3. - Truck maintenance accidents, by capacity, compared with truck population<sup>1</sup>

| Capacity, st       | Accidents |       | Population, pct |
|--------------------|-----------|-------|-----------------|
|                    | Number    | pct   |                 |
| 50 to 85.....      | 257       | 64.4  | 31.6            |
| 90 to 145.....     | 92        | 23.1  | 42.5            |
| Over 150.....      | 50        | 12.5  | 25.9            |
| Total specified    | 399       | 100.0 | 100.0           |
| Not specified..... | 826       | NAp   | NAp             |
| Total accidents    | 1,225     | NAp   | NAp             |

NAp Not applicable.

<sup>1</sup>Estimated based on truck manufacturer information, conversations with industry consultants, and surveys conducted by Engineering and Mining Journal (5) and Coal Age (2).

A comparison of older haulage trucks with newer models indicates that progress has been made with regard to their human factors and ergonomic design, but most of the changes have related either to the equipment operator's safety and comfort or to the production aspects of the truck (1).

dropped. Maintenance personnel should make better use of lifting equipment, or use additional people for handling such heavy parts and components as drive trains, tires and wheels, or suspensions. Job training to improve employee awareness of equipment size and the correct tools for handling various components are needed (1, 3, 12).

TABLE 4. - Truck maintenance accidents, by activity of the injured

| Activity                     | Number | pct   |
|------------------------------|--------|-------|
| Removing-replacing parts.... | 310    | 26.5  |
| Servicing equipment.....     | 296    | 25.3  |
| Getting on and off equipment | 245    | 20.9  |
| Shop area activity.....      | 175    | 14.9  |
| Inspection.....              | 107    | 9.1   |
| Cleaning.....                | 39     | 3.3   |
| Total specified.....         | 1,172  | 100.0 |
| Not specified.....           | 53     | NAp   |
| Total accidents.....         | 1,225  | NAp   |

NAp Not applicable.

The job activities that contribute most to injuries include (3)--

Limited aids for material handling (e.g., lifting devices, jacks, hoists);

Lack of effective training programs and work procedures for manual material handling, typified by the prevailing attitude that back injuries due to lifting "will not happen to me";

Inadequate workstands or platforms for support during tasks requiring reaching or lifting;

Inadequate use of personal protection equipment such as gloves, lifelines, or hearing protection; and

Lack of supervision.

Table 5 summarizes haulage truck maintenance accidents by source injury. This information reveals that the work station was the most prevalent source, accounting for 35.5 pct of the accidents: this would be the area adjacent to and around the equipment being serviced, including makeshift supports, ladders, workstands, shop equipment, or the shop floor.

TABLE 5. - Truck maintenance accidents, by source of injury

| Source of injury                                      | Number | pct   |
|-------------------------------------------------------|--------|-------|
| Work station <sup>1</sup> .....                       | 431    | 35.5  |
| Truck body and/or large components <sup>2</sup> ..... | 246    | 20.3  |
| Truck parts or components <sup>3</sup> ..             | 230    | 19.0  |
| Tools and equipment.....                              | 114    | 9.4   |
| Shop area hazards.....                                | 90     | 7.4   |
| Tires, wheels, hubs, or rims                          | 80     | 6.6   |
| Heat or flames.....                                   | 23     | 1.8   |
| Total specified.....                                  | 1,214  | 100.0 |
| Not specified.....                                    | 11     | NAp   |
| Total accidents.....                                  | 1,225  | NAp   |

NAp Not applicable.

<sup>1</sup>Area immediately around vehicle being repaired.

<sup>2</sup>Components requiring mechanical handling with cranes or special equipment.

<sup>3</sup>Includes most components that can be reasonably handled by 1 person.

The truck body or large components accounted for about one-fifth of all accidents, by source of injury (12). Two fatalities occurred in 1980 as a result of failure to secure the truck box during maintenance, and numerous injuries and near misses have occurred. There should be a definite means of securing truck boxes using locking pins or other such devices, as well as training to ensure mechanics use these devices correctly.

Over the 7-yr period, tools and equipment were involved in about 10 pct of all accidents, and they were a contributing factor in the majority of accidents (12). Table 6 lists accidents by tools and equipment. Shop equipment was involved in 48.2 pct of the truck maintenance accidents where the tools and equipment involved in the accident were specified. Shop equipment includes the great variety of job aids that are used within the shop area, such as cranes, air compressors, hydraulic jacks, hoses, or tire changers. Some of the most hazardous types of shop equipment are hoisting apparatus, involved in 10.3 pct of all accidents, water hoses in 6.3 pct, steam cleaners in 4.0 pct, and hydraulic jacks in 3.7 pct (12).

Nonpowered handtools accounted for over one-third of all injuries. The accident data indicate that mechanics are eight times more likely to be injured using handtools than power tools, clearly showing the advantage of reducing manual exertion. The design of handtools could be substantially improved. Maintenance of the mine off-highway trucks is complex and specialized, and usually must be accomplished without conventional handtools

TABLE 6. - Truck maintenance accidents, by tools and equipment

| Tools and equipment          | Number | pct   |
|------------------------------|--------|-------|
| Shop equipment.....          | 131    | 48.2  |
| Nonpowered handtools.....    | 101    | 37.1  |
| Welding, cutting equipment.. | 28     | 10.3  |
| Power handtools.....         | 12     | 4.4   |
| Total specified.....         | 272    | 100.0 |
| Not specified.....           | 953    | NAp   |
| Total accidents.....         | 1,225  | NAp   |

NAp Not applicable.

and small power tools. Without knowledge about or availability of specially designed tools, shop personnel often resort to (1, 3)--

Unsafe practices and procedures;

Locally designed and/or fabricated tools; and

Misuse of available tools.

Mechanics should be trained to use the right tool for the task, and supervisors should take more responsibility in insuring that the right tools are used. Also, the importance of tool maintenance and proper storage is again emphasized.

Maintenance accidents are usually multifaceted in nature; although the primary cause of the accident could be human error, there could still be contributing factors, such as truck design problems, tool equipment considerations, and other unsafe conditions. Table 7 lists accidents by unsafe conditions (12). The unsafe conditions present at the time of the accident are those factors that contributed to the probability or severity of an accident. By understanding the unsafe conditions present within the accident scenario, the accident could possibly be prevented or the degree of injury minimized.

In roughly one-fourth of all accidents, inadequate truck design was the apparent unsafe condition. Poor access (partially a truck design problem) and poor work platforms together comprise 21.4 pct of all accidents, illustrating again the need for adequate access for maintenance. In 26.5 pct of all accidents analyzed there was no apparent unsafe condition.

TABLE 7. - Truck maintenance accidents, by unsafe condition

| Unsafe condition                      | Number | pct   |
|---------------------------------------|--------|-------|
| Truck design deficiencies...          | 300    | 24.7  |
| Poor access.....                      | 132    | 10.9  |
| Wrong tools or equipment....          | 131    | 10.8  |
| Poor work platform.....               | 127    | 10.5  |
| Inadequate employee training.....     | 106    | 8.7   |
| Shop hazards.....                     | 96     | 7.9   |
| No identifiable unsafe condition..... | 321    | 26.5  |
| Total specified.....                  | 1,213  | 100.0 |
| Not specified.....                    | 12     | NAP   |
| Total accidents.....                  | 1,225  | NAP   |

NAP Not applicable.

These accidents are due to either human error, such as misjudgment on the part of the employee, or due to chance error, where the mechanic is performing a maintenance task with proper tools in the recommended way, and an accident occurs because of the tool breaking. On the other hand, inadequate employee training (8.7 pct) involves human error accidents where training may have in some way mitigated or prevented the injury.

In the discussion of the primary cause of truck maintenance accidents, 63.6 pct of all accidents were attributed to unsafe actions, or human error, on the part of the employee. Combining this information with that of table 7, where 26.5 pct of all accidents had no unsafe condition evident, it can be concluded that a significant proportion of human-error accidents could possibly be prevented or mitigated through equipment redesign for serviceability, training, or other maintenance improvements (12).

#### SUMMARY AND CONCLUSIONS

Overall, young, inexperienced workers are involved in most haulage truck maintenance accidents. A typical maintenance accident involves a male mechanic under 33 yr old, with under 5 yr job experience. Based on the review and interpretation of 1,225 haulage truck

maintenance accident reports, the major factors in haulage truck maintenance accidents appear to be--

Lack of safety awareness or inability to measure and judge the job requirement by either the employee or the supervisor;

Poor access to working spaces on equipment, which forces the employee to take an unsafe position;

Lack of craft training for specialized maintenance tasks;

Poor tools and equipment with regard to condition or design;

Choice of the wrong tool or ancillary equipment for the job;

Increased hazards of doing repair work in the field;

Insufficient methods of handling large, heavy truck parts and components;

Poor design or housekeeping of the shop work station or platform;

Inadequate service manuals and diagnostic aids that could help the mechanic start the task properly; and

Use of untrained mine equipment operators and laborers to perform the maintenance and repair tasks.

It is the purpose of this report to characterize haulage truck maintenance and repair hazards in U.S. surface mines.

The data presented should help the mining industry, equipment manufacturers, MSHA, and the Bureau to further pinpoint specific recommendations to combat the increasing hazards surrounding haulage truck maintenance. The approach has been to determine where and how maintenance personnel have been injured. Future research will address methods to alleviate specific hazardous situations, and provide further recommendations.

To reduce injuries in U.S. surface mines, maintenance and repair is a key area on which to focus attention, and this area may well be a new frontier for safety professionals. Because of the difficulty in analyzing maintenance activities and the great variety of job procedures, tools, equipment, and shop conditions, a lack of safety awareness as to the hazards involved with mine haulage truck maintenance seems to be present. Not surprising, the maintenance and repair function is a difficult area to supervise. This difficulty contributes to the growing safety hazard as well as to the high cost of the overall operation.

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